EVALUATION OF NUTRITIVE VALUE AND IN VITRO METHANE PRODUCTION OF FEEDSTUFFS FROM AGRICULTURAL AND FOOD INDUSTRY BY-PRODUCTS

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ABSTRACT

The aim of this research was to evaluate the nutrient degradability, in vitro methane (\(\text{CH}_4\)) production of several agricultural and food industry by-products in relation to their chemical composition. Twenty-one samples of 7 feedstuffs from agricultural and food industry by-products consisted of corn straw, potato straw, rice straw, cocoa pod, sago waste, rice bran, soybean curd residue were evaluated by an in vitro gas production and nutrient degradability. The feedstuffs varied greatly in their crude protein (CP), neutral detergent fiber (NDF) and non-fiber carbohydrate (NFC) contents. Crude protein ranged from 1.5 to 21.8%, NDF from 31.6 to 71.1% and NFC from 1.5 to 50.8%. Among the seven feedstuffs, soybean curd residue had the highest CP content, on the other hand it had the lowest NDF content. Dry matter (DM) and organic matter (OM) degradability were highest (\(P<0.01\)) in soybean curd residue among the feedstuffs. The \(\text{CH}_4\) production was significantly higher (\(P<0.01\)) in rice straw, cocoa pod and corn straw as compared to sago waste. There was a strong positive correlation \((r = 0.60; P<0.01)\) between NDF concentration and \(\text{CH}_4\) production. However, the total gas productions was negatively correlated \((r = -0.75; P<0.01)\) with NDF content. The \(\text{CH}_4\) production of feedstuff is influenced by NDF content.


INTRODUCTION

Feed availability as quality, quantity or continuity is important factor to support development of animal production system. In the tropical country such as Indonesia, grass production is very much during wet season, but during dry season its production is limited, thus most of farmers have problem to serve forage for ruminants. Leng (1990) reported that most of farmers in tropical and subtropical countries used agricultural by-product as major component of diet for large ruminant for considerable part of or throughout the year.

Generally, agricultural by-products have low quality because they have high crude fiber content but low crude protein and digestibility value. However, ruminants have ability to convert low-quality forages become useful products as meat and milk for human. Methane (\(\text{CH}_4\)) produced during digestion in the rumen represents energy loss to the host animal and contributes to global warming. Kurihara et al. (1999) stated that \(\text{CH}_4\) production in cattle fed on tropical forage diet was higher than those fed on temperate forage diet, due to grass in the tropics containing high crude fiber and lignin but low non-structural carbohydrate than grass in the subtropics.

According to Estermann et al. (2002) there was a strong relationship between \(\text{CH}_4\) production and NDF intake and NDF digested. Santoso et al. (2007) also observed a strong relationship between \(\text{CH}_4\) production \((\text{g/day})\) and NDF digested \((\text{g/day})\) \((r = 0.88)\). In other study, Moss et al. (2002) concluded that \(\text{CH}_4\) production has positive correlation with NDF content \((R^2=79\%)\).

The \(\text{CH}_4\) production has a negative correlation with energy utilization in ruminants. Energy lost as \(\text{CH}_4\) from mature cattle ranges from 2 to 12% of gross energy intake. The range in \(\text{CH}_4\) emissions is
due to mainly to the level of feed intake and the composition of the diet (Johnson and Johnson, 1995).

Measurement of CH$_4$ in feedstuffs from agricultural and food industry by-products as sole feed or concentrate component in Indonesia are limited. Based on above reasons, a study is needed to evaluate nutrient degradability i.e. dry matter (DM) and organic matter (OM), fermentation characteristics, CH$_4$ production in feedstuffs from agricultural and food industry by-product.

**MATERIALS AND METHODS**

**Preparation of Feedstuffs**

Twenty-one samples of 7 feedstuffs from agricultural and food industry by-products consisted of corn straw, potato straw, rice straw, cocoa pod, sago waste, rice bran, soybean curd residue were used in *in vitro* nutrient degradability and gas production. Each feedstuff was collected from district of Manokwari, Prafi and Oransbari. Samples which contained less than 20% dry matter were oven dried at 60 ºC for 48 h, then ground to pass a 1 mm sieve in a Wiley mill.

**Donor Animal**

Two ruminally fistulated Ongole crossbreed cattle were used as rumen liquor donor. Animals were fed twice daily (08:00 and 16:00 h) at maintenance level of DM intake with a basal diet consisting of elephant grass and concentrate (70 : 30, on DM basis).

**In vitro Gas Production Test**

Gas production measurement was conducted according to method of Menke and Steingass (1988), as previously described by Santoso and Hariadi (2008). Samples (300 ± 10 mg) were weighed into 100 ml glass syringes (Model Fortuna, Häberle Labortechnik, Germany). Buffered mineral solution was prepared just before experiment and placed in a water bath under continuous flushing with CO$_2$. About 30 ml of rumen liquor-buffer mixtures in a 1 : 4 (v/v) ratio were dispensed in 100 mL glass tubes containing 250 mg of dry sample. After gassing CO$_2$ in the tube, corks were tightly placed over the tubes and were incubated in a water bath at 39 ºC for 48 h. After 48 h of incubation, the contents were filtered through pre-weighed Gooch crucibles and dried at 105 ºC for 24 h. The percent loss in weight was determined and presented as DM degradability. The residue left was ashed at 550 ºC for determination of OM degradability.

**Sample Analyses**

The DM, ash, crude protein and ether extract (EE) of samples were analyzed according to method described by Harris (1970), whereas NDF content analysis was according to Van Soest *et al.* (1991). The NFC concentration was calculated as OM – (CP + NDF + EE) (Kurihara *et al.*, 1999).

**Experimental Design and Statistical Analysis**

The experiment was arranged in completely randomized design consisted of 7 feedstuffs with 3 replications. Data were analyzed using analysis of variance using general linear model procedure of SAS. Treatment means were separated by applying Duncan’s multiple range test with a probability level of $P=0.01$. Pearson correlation was used to establish the correlations among variables.

**RESULTS AND DISCUSSION**

Chemical composition of feedstuffs used in this study is presented in Table 1. Soybean curd waste had the highest CP content (21.8 4.6%), and sago waste was observed to be the lowest (1.4 ± 0.2%). The CP content of soybean in this research was similar to value of 23.6% as reported by Wina *et al.* (2008),...
however Kondo et al. (1996) reported that DM and CP contents of soybean curd waste were 17.9% and 26%, respectively. The CP concentration of potato straw and corn straw in this study was higher than CP content of potato straw (11.3%) and corn straw (7.4%) as reported by Tangendjaja and Gunawan (1988). Concentration of CP of sago waste in this study was comparable to value of 0.98% as reported in earlier study (Kumoro et al., 2008). In addition, CP and EE contents of rice straw in this study were similar to result of Utomo (2004) that 5.72% and 1.50%, respectively. The NDF content of rice straw was lower than result of Liu et al. (2002) with NDF concentration 71.1%. The different result of this study as compared to other study could be due to different of planting location, harvest time and variety. Crowder and Chheda (1982) suggested that the minimum level of feed CP for fermentation and degradation in the rumen is 7%. However, a study with tropical grass Minson (1990) noted that rumen bacteria need 6% of CP for normal activity. Based on Table 1, using sago waste as ruminant’s feed required other feedstuff which has high CP. Sago waste contains the lowest EE content but the highest NFC. Rice straw had the highest NDF content and the concentration was similar with value of 72.5% as reported by Wang et al. (2006). High NDF content in rice straw (71.1%) caused low in NFC content. The CP content of rice bran in this study was similar with result of Prasetyono et al. (2007). Tangendjaja (1990) reported that CP content of rice bran with some milling levels ranged from 14.23 to 15.10%.

The DM and OM degradability of soybean curd waste was higher (P<0.01) than other feedstuffs. In addition, DM degradability on corn straw, sago waste, potato straw and rice bran were higher than cocoa pod and rice straw. The higher DM degradability in soybean curd waste could be due to high CP content, possibly resulting in increased activity and microbe population during fermentation. This condition was followed by increasing in DM and OM degradability. Even though sago waste contained the lowest CP, NDF content was also low thus DM degradability was not too low. In contrast, rice straw had the highest NDF content (71.1%), causing the lowest DM and OM degradability. Tangendjaja (1990) stated that the \textit{in vitro} DM digestibility of rice straw was 35.4%. Moreover, in general the \textit{in vitro} DM digestibility this feedstuff was below 40%. The DM degradability of corn straw in this study was higher than value of 32.7 (Tangendjaja and Gunawan, 1988). This is could be affected by good quality of corn straw especially CP content. Eventhough NDF concentration of rice bran was lower than potato straw, DM degradability of potato straw was higher (P<0.01) than rice bran. It could be due to high lignin and silica contents in rice straw. Ibrahim (1995) reported that \textit{in vitro} OM digestibility of rice bran was low caused by high lignin and silica contents. Leng (1990) defined that low-quality grass is indicated by low digestible value (< 55%) and low CP concentration (< 8%). Based on these criteria, sago waste, rice straw and cocoa pod are classified into low-quality feedstuffs.

Gas produced in \textit{in vitro} experiment as result of substrate fermentation by microbe (CO$_2$ + CH$_4$) and buffer bicarbonate during fermentation (CO$_2$) (Getachew et al., 1998). On average gas produced at 24 h of incubation was 87% of total gas produced by 48 h of incubation. This indicates that gas production rate decreased with increasing incubation time due to reducing substrate for fermentation process. Getachew et al. (2005) reported that gas

### Table 1. Chemical Composition of Feedstuffs (%) from Agricultural and Food Industry By-product

<table>
<thead>
<tr>
<th>Feedstuffs</th>
<th>DM</th>
<th>OM</th>
<th>CP</th>
<th>EE</th>
<th>NDF</th>
<th>NFC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn straw</td>
<td>24.6</td>
<td>91.2</td>
<td>11.9</td>
<td>8.0</td>
<td>63.0</td>
<td>8.3</td>
</tr>
<tr>
<td>Potato straw</td>
<td>14.2</td>
<td>88.9</td>
<td>15.6</td>
<td>11.1</td>
<td>42.3</td>
<td>19.9</td>
</tr>
<tr>
<td>Rice straw</td>
<td>82.3</td>
<td>81.1</td>
<td>6.8</td>
<td>1.7</td>
<td>71.1</td>
<td>1.5</td>
</tr>
<tr>
<td>Cocoa pod</td>
<td>16.1</td>
<td>90.3</td>
<td>6.8</td>
<td>5.1</td>
<td>47.7</td>
<td>30.7</td>
</tr>
<tr>
<td>Sago waste</td>
<td>6.8</td>
<td>91.4</td>
<td>1.5</td>
<td>0.8</td>
<td>38.3</td>
<td>50.8</td>
</tr>
<tr>
<td>Rice bran</td>
<td>87.1</td>
<td>88.7</td>
<td>9.4</td>
<td>9.9</td>
<td>36.6</td>
<td>32.8</td>
</tr>
<tr>
<td>Soybean curd residue</td>
<td>12.1</td>
<td>96.2</td>
<td>21.8</td>
<td>8.0</td>
<td>31.6</td>
<td>34.8</td>
</tr>
</tbody>
</table>

DM: dry matter; OM: organic matter; CP: crude protein; EE: ether extract; NDF: neutral detergent fiber; NFC: non-fiber carbohydrate; SE: standard of error
produced at 24 h of incubation averaged 89% of total gas produces at 48 h. Gas production in soybean curd waste and sago waste at 24 and 48 h was higher (P<0.01) than other feeds, and the lowest was found in rice straw (Table 2). Gas production of each feedstuff gets a long with OM degradability, as showed by correlation coefficient (r) between these variables was 0.75. In contrast, gas production was negative correlated with NDF content (r = -0.75). This result was in agreement with Getachew et al. (1998) result with value was -0.24. Rice straw had the lowest gas production among 7 feedstuffs tested in this study. However, gas production in rice straw was lower than reported by Wang et al. (2006) that gas production at 24 and 48 h of incubation were 35 and 44.2 ml/200 mg of substrate, respectively. The different in both results could be caused by differences in rice straw quality and rumen liquor source in in vitro experiment. There was positive correlation between CP content and gas production at 48 h of incubation and this result was consistent with result of Ndlovu and Nherera (1997) and Larbi et al. (1998) that r value was 0.16 and 0.39 respectively.

The CH$_4$ is produced by reduction of CO$_2$ and H$_2$ which catalyzed by enzyme secreted by methanogen. The CO$_2$ and H$_2$ are mainly produced during fermentation of structural carbohydrate i.e. hemicellulose (Takahashi, 2001). Methane production (ml/g DM) in rice straw, corn straw and cocoa pod was higher (P<0.01) as compared to soybean curd waste. High CH$_4$ production in those feedstuffs could be due high NDF content. The relationship between CH$_4$ production and NDF concentration was indicated with positive coefficient of correlation (r = 0.60; P<0.01). In contrast, NFC content had negative correlation with CH$_4$ production (r = -0.34). Santos et al. (2007) concluded that there was strong correlation between CH$_4$ production (g/day) and NDF digested (g/day) ($R^2$=0.88). In addition, Moss et al. (2002) revealed that CH$_4$ production had positive correlated with NDF content ($R^2$=79%) and negative correlated with CP content ($R^2$=-76.8%). Average percentage of CH$_4$ from total gas production was 19%, which the highest was observed in rice straw and the lowest in soybean curd waste. In in vitro study, Getachew et al. (2005) reported that proportion CH$_4$ of the total gas was 16%, whereas Thalib (2008) found 22.5% CH$_4$ production.

Concentration NH$_3$-N in soybean curd waste was higher (P<0.01) as compared to other feedstuff, and the lowest was observed in sago waste. Concentration of N-NH$_3$ in both feedstuffs was consistent with crude protein content. This result was supported by strong correlation between CP content and NH$_3$-N as indicated with $r = 0.83$ (Table 4). Among 7 feedstuffs tested, concentration NH$_3$-N in sago waste was below normal range (7 mg N/100 ml) that recommended for maximum microbial N synthesis (Okorie et al., 1977). Based on this result, it is recommended to combine sago waste with other

### Table 2. Gas Production and Coefficient of Nutrient Degradability of Feedstuffs after 24 and 48 h of incubation

<table>
<thead>
<tr>
<th>Feedstuffs</th>
<th>Gas (ml/g DM)</th>
<th>Degradability (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24 h</td>
<td>48 h</td>
</tr>
<tr>
<td>DM</td>
<td></td>
<td>DM</td>
</tr>
<tr>
<td>OM</td>
<td></td>
<td>OM</td>
</tr>
<tr>
<td>Corn straw</td>
<td>150.6$^{bc}$</td>
<td>173.6$^{c}$</td>
</tr>
<tr>
<td>Potato straw</td>
<td>180.9$^{b}$</td>
<td>209.0$^{b}$</td>
</tr>
<tr>
<td>Rice straw</td>
<td>134.3$^{c}$</td>
<td>157.2$^{c}$</td>
</tr>
<tr>
<td>Cocoa pod</td>
<td>162.4$^{bc}$</td>
<td>186.5$^{bc}$</td>
</tr>
<tr>
<td>Sago waste</td>
<td>220.0$^{a}$</td>
<td>253.4$^{a}$</td>
</tr>
<tr>
<td>Rice bran</td>
<td>151.1$^{bc}$</td>
<td>179.3$^{bc}$</td>
</tr>
<tr>
<td>Soybean curd residue</td>
<td>249.2$^{a}$</td>
<td>274.6$^{a}$</td>
</tr>
<tr>
<td>S.E</td>
<td>7.70</td>
<td>7.31</td>
</tr>
<tr>
<td>P</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

DM: dry matter; OM: organic matter; SE: standard of error
Means with a column with different letters are significantly different (P<0.01)
Nutritive Value of Feedstuffs from Agricultural By-product (B. Santoso and B.T. Hariadi)

feedstuffs which had high CP content. Total VFA concentration in soybean curd waste was higher (P<0.01) than other feedstuffs and the lowest was found in rice straw. Total VFA concentration in those feedstuffs was supported by OM degradability. The same pattern was also shown in acetate and propionate concentrations in soybean curd waste were higher than other feedstuffs. The ratio of acetate (C2) to propionate (C3) in cocoa pod and corn straw was higher than other feedstuffs. This indicates that high proportion of the potential NDF digested in both feedstuffs.

CONSLUSION

Feedstuffs from agricultural and food industry by-products varied greatly in their CP, NDF and NFC contents. Soybean curd waste had the best nutritive value as compared to other feedstuffs, as indicated by high CP content, and DM and OM degradability. There was positive correlation (r=0.60) between NDF content and CH4 production (ml/g DM). However, NDF content was negative correlated (r = 0.75) with gas production (ml/g DM). Rice straw had the highest CH4 production and sago waste had the lowest CH4 production. The CH4 production of feedstuff is influenced by NDF content.

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